

Heavy Flavour Physics at CDF

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The CDF detector at Fermilab has accumulated more than 3 fb^{-1} of data which enables unprecedented studies of heavy flavor hadron properties. We present recent CDF measurements of mass and lifetime of the B_c meson as well as lifetime, mixing and CP violation properties of B_s mesons.

1. Introduction

We review recent measurements of B_c and B_s meson properties performed with the CDF detector in $\sqrt{s} = 1.96 \text{ TeV}$ $p\bar{p}$ collisions at the Tevatron. Due to the excellent performance of the Tevatron the CDF experiment has recorded 3.5 fb^{-1} of data by June 2008. The measurements presented here use between 1 fb^{-1} and 2.4 fb^{-1} . The CDF detector is described in detail in Ref. [1].

At the Tevatron, B hadrons are mostly produced in pairs. The main $b\bar{b}$ production mechanism is flavor creation through gluon fusion. The $b\bar{b}$ production cross section of $\sim 30 \text{ } \mu\text{b}$ [1] is large compared to B-factories which enables rich B Physics programs at the Tevatron. However, the Tevatron $b\bar{b}$ cross section is orders of magnitude smaller than the total inelastic cross section of $\sim 50 \text{ mb}$. For this reason, CDF employs triggers that select events with signatures specific to various B decays. The measurements presented here uses data selected by the di-muon trigger, geared towards $B \rightarrow J/\psi X$ decays and by the displaced track trigger used for measurement of B_s lifetime in $B_s \rightarrow D_s \pi X$ decays.

2. Mass and Lifetime of B_c Mesons

The B_c meson is unique as it contains two heavy quarks: b (bottom) and \bar{c} (anti-charm). Different theoretical models predict the B_c mass around $6.3 \text{ GeV}/c^2$. In particular, non-relativistic potential models [2] predict the range $6247 - 6286 \text{ MeV}/c^2$. Lattice QCD models [3] predict

$6304 \pm 12_{-0}^{+18} \text{ MeV}/c^2$, while similar results are determined in perturbative QCD calculations [4].

The lifetime of the B_c meson is expected to be $\sim 0.5 \text{ ps}$ [5] which is about a third of the typical light B meson lifetime of $\sim 1.5 \text{ ps}$. The short lifetime is explained by the fact that either the b or the c quarks can decay weakly through a W boson. When the b quark decays, the final state contains a charmonium particles while the decay of the c quark results in a B meson final state. Additionally, the b and c quarks can annihilate, for example into a lepton and neutrino final state. The measurement presented here use $B_c \rightarrow J/\psi l \nu X$ decays, where the lepton is either a muon or electron.

2.1. Measurement of B_c Mass

The mass of the B_c meson was measured for the first time by the CDF experiment in Run I [6] using inclusive semileptonic decays $B_c \rightarrow J/\psi l \nu X$. Since the B_c meson was not fully reconstructed due to the missing neutrino, the result had large uncertainties $6400 \pm 390(\text{stat.}) \pm 130(\text{syst.}) \text{ MeV}/c^2$.

The most precise measurement of the B_c mass was recently performed by the CDF experiment using 2.4 fb^{-1} of data [7] using the fully reconstructed decay mode $B_c \rightarrow J/\psi \pi$. The advantage of using fully reconstructed decays is that the mass of the decaying particle can be measured precisely by fitting the invariant mass distribution. The measurement was performed using data collected by the CDF J/ψ trigger. This trigger requires two muons of opposite charge, transverse

momentum larger than 1.4 GeV/c and invariant mass close to the J/ψ mass. The data sample used in this analysis contains ~ 17 million J/ψ candidates reconstructed with an average mass resolution of $13 \text{ MeV}/c^2$.

Using this initial J/ψ sample, both $B^+ \rightarrow J/\psi K^+$ and $B_c \rightarrow J/\psi \pi^+$ decays are reconstructed. The B^+ sample is used to determine an optimal set of selection requirements that are subsequently used for the B_c selection. This procedure accounts for the expected shorter B_c lifetime by using only B^+ mesons with decay time in ranges typical to expected B_c lifetime: $80 < ct < 300 \mu\text{m}$.

The invariant mass distribution of the B_c candidates is shown in Figure 1. The mass of the B_c meson is determined using an un-binned log likelihood method. The signal probability density function (PDF) is described by a Gaussian function with a width proportional to the estimated mass uncertainty estimated from track uncertainties. The background PDF includes both a combinatorial component as well as a component from $B_c \rightarrow J/\psi K^+$ Cabibbo suppressed decays.

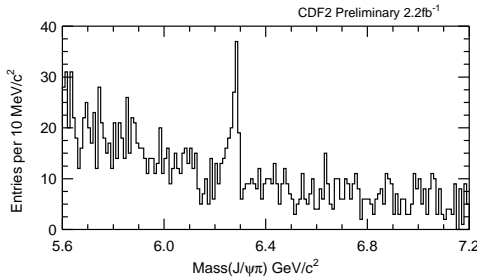


Figure 1. B_c invariant mass distribution reconstructed from $B_c \rightarrow J/\psi \pi$ decays.

The total B_c signal yield is estimated to 108 ± 15 candidates with a statistical significance of 8 standard deviations. The measured mass is $6275.6 \pm 2.9 \text{ MeV}/c^2$. The largest systematic uncertainty of $2.2 \text{ MeV}/c^2$ is due to the knowl-

edge of the scale factor on mass uncertainties. The total systematic uncertainty which includes effects due to misalignment, momentum scale and Cabibbo suppressed $B_c \rightarrow J/\psi K^+$ decays is estimated to $2.5 \text{ MeV}/c^2$, comparable but slightly lower than the statistical error, leading to the most precise measurement of the B_c mass: $6275.6 \pm 2.9(\text{stat.}) \pm 2.5(\text{syst.}) \text{ MeV}/c^2$, in good agreement with the corresponding D0 measurement [9] $6300 \pm 14(\text{stat.}) \pm 5(\text{syst.}) \text{ MeV}/c^2$.

2.2. Measurement of B_c Lifetime

The lifetime of the B_c meson is measured by the CDF experiment using partially reconstructed semileptonic $B_c \rightarrow J/\psi (\mu\mu) l \nu X$ decays [10] in 1.0 fb^{-1} of data. The lepton l can be either a muon or an electron. The data sample is selected by the same J/ψ trigger used for the B_c mass measurement. The lifetime analysis starts with a sample of ~ 5.5 million $J/\psi \rightarrow \mu^+ \mu^-$ candidates. A third lepton is then required to come from the same vertex as J/ψ . The main challenges in this measurement are the partially reconstructed momentum of the B_c meson and multiple backgrounds.

Since the momentum of the B_c meson is not fully reconstructed, the observed pseudo proper decay time $ct^* = \frac{m L_{xy}(J/\psi l)}{p_T(J/\psi l)}$ is statistically corrected by a factor $K = \frac{p_T(J/\psi l)}{p_T(B_c)}$ determined from simulation. Here, m is the mass of the B_c meson [8], $p_T(J/\psi l)$ is the reconstructed transverse momentum of the J/ψ and lepton, $p_T(B_c)$ is the true transverse momentum of the B_c meson determined from simulation and L_{xy} is the transverse B_c decay length projected on the reconstructed transverse momentum.

In this measurement the mass of the B_c meson is not reconstructed due to the missing neutrino. Instead, the $J/\psi l$ mass is used. However, this quantity has a wide distribution and sidebands cannot be used to estimate backgrounds as in fully reconstructed decays. Different background contributions are determined using data-driven methods when possible and simulation otherwise. The main sources of backgrounds are: fake leptons, fake J/ψ , “ $b\bar{b}$ sources”, e^+e^- from either photon conversions or decays of π^0 and η mesons

and prompt J/ψ events. The fake lepton background is produced by a real J/ψ and a random track which fakes a muon or an electron and forms a $J/\psi l$ vertex that satisfies the vertex quality requirements. The fake lepton fractions are determined using real pions and kaons from $D^{*+} \rightarrow D^0 \pi^+$ with $D^0 \rightarrow \pi^+ K^-$ and real protons from $\Lambda \rightarrow p^+ \pi^-$, where the real pions, kaons and protons are misidentified as leptons. The fake J/ψ background is modeled using the J/ψ mass sidebands. $b\bar{b}$ backgrounds are events with a real J/ψ from one b quark and a real lepton from the other \bar{b} anti-quark in the event. This background is modeled using Pythia [11] simulation where the fractions of the three main production mechanisms, flavor creation, flavor excitation and gluon splitting are tuned to data using the angular separation between the J/ψ and the lepton as discriminating variable. e^+e^- backgrounds, specific to $J/\psi e$ mode only, are suppressed by trying to identify both the positron and electron from photon conversion or light meson decay. The residual e^+e^- pairs are modeled using Pythia [11] simulation. The background fraction from prompt J/ψ is modeled by a Gaussian function in the pseudo proper decay space and determined directly from the un-binned likelihood fit.

The B_c lifetime is measured separately in $J/\psi e$ and $J/\psi \mu$ channels using un-binned likelihood methods. The fit projections of the pseudo proper decay time distributions in the $J/\psi \mu$ channel is shown in Figure 2.

The corresponding lifetimes are: $c\tau_\mu = 179.1^{+32.6}_{-27.2}(\text{stat.})$ and $c\tau_e = 121.7^{+18.0}_{-16.3}(\text{stat.}) \mu\text{m}$. The main sources of systematic uncertainties come from our understanding of the decay time resolution function ($3.8 \mu\text{m}$) and from relative fractions of $b\bar{b}$ production mechanisms in Pythia simulation. The total systematic uncertainty is $5.5 \mu\text{m}$, leading to a combined measurement of the B_c lifetime of $c\tau_\mu = 142.5^{+15.8}_{-14.8}(\text{stat.}) \pm 5.5(\text{syst.}) \mu\text{m}$. This agrees well with a similar recent measurement performed by the D0 experiment [12] in the $B_c \rightarrow J/\psi \mu \nu X$ channel $c\tau = 134.4^{+11.4}_{-10.8}(\text{stat.}) \pm 9.6(\text{syst.}) \mu\text{m}$. Figure 3 shows a summary of the experimental results of the B_c lifetime. CDF and D0 measurements agree well with the theoretical predictions and with each

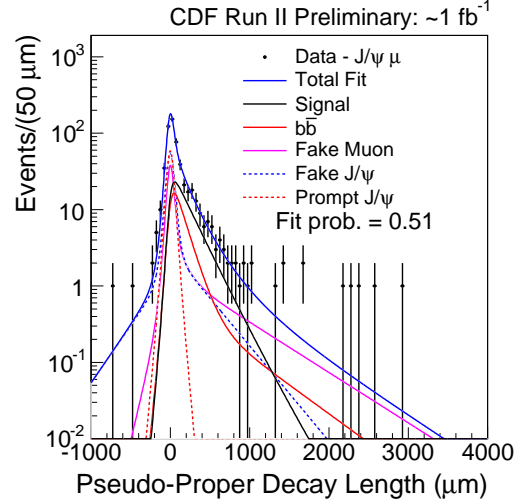


Figure 2. Pseudo proper decay time fit projections in $B_c \rightarrow J/\psi \mu \nu X$ channel.

other and have similar uncertainties.

3. Neutral B_s System

A B_s^0 meson is a bound state composed of an anti-bottom quark \bar{b} and a strange s quark. The time evolution of a mixture of the B_s^0 and its antiparticle \bar{B}_s^0 , $a(t)|B_s^0\rangle + b(t)|\bar{B}_s^0\rangle$, is given by the Schrödinger equation

$$i \frac{d}{dt} \begin{pmatrix} a \\ b \end{pmatrix} = \left(M - i \frac{\Gamma}{2} \right) \begin{pmatrix} a \\ b \end{pmatrix}, \quad (1)$$

where M and Γ are 2×2 mass and decay matrices. The mass eigenstates B_L^0 and B_H^0 are linear combination of the flavor eigenstates B_s^0 and \bar{B}_s^0 and are obtained by diagonalizing the mass operator. The mass difference Δm_s is proportional to the B_s mixing frequency recently measured by both CDF [13] and D0 [14] experiments and found to be in good agreement with Standard Model (SM) predictions [17]. Moreover, the mass eigenstates have different decay widths (lifetimes) Γ_L and Γ_H . The average decay width is defined as $\Gamma = (\Gamma_L + \Gamma_H)/2$ and the decay width difference is defined as $\Delta\Gamma = \Gamma_L - \Gamma_H$. The decay

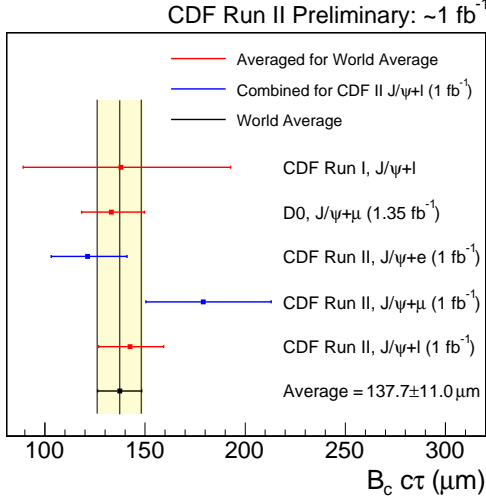


Figure 3. Summary of the B_c lifetime experimental results.

width difference $\Delta\Gamma = 2|\Gamma_{12}|\cos(\phi_s)$ is sensitive to new physics (NP) effects [15–17] that affect the phase $\phi_s = \arg(-M_{12}/\Gamma_{12})$, where Γ_{12} and M_{12} are the off-diagonal elements of the mass and decay matrices. New physics will increase ϕ_s , so $\Delta\Gamma$ would be smaller than the SM prediction. Since the SM phase ϕ_s^{SM} is predicted to be very small (~ 0.004) [17], in a new physics scenario with large contribution to ϕ_s one could approximate $\phi_s = \phi_s^{SM} + \phi_s^{NP} \approx \phi_s^{NP}$. If real, this new physics phase is accessible in $B_s \rightarrow J/\psi\phi$ decays. In these decays one can measure the CP violation phase β_s which is the relative phase between the direct decay amplitude and mixing followed by decay amplitude. In SM this phase is defined as $\beta_s^{SM} = \arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right)$ [17], where V_{ij} are the elements of the CKM quark mixing matrix. Global fits of experimental data tightly constrain the CP violation phase to small values in the context of SM $\beta_s^{SM} \approx 0.02$ [18]. The presence of new physics could modify this phase by the same quantity ϕ_s^{NP} that affects the ϕ_s^{SM} phase. New physics could contribute significantly to the observed β_s phase [15–17] expressed as

$2\beta_s = 2\beta_s^{SM} - \phi_s^{NP}$. Assuming that new physics effects dominate over the SM phase, we can approximate $2\beta_s \approx -\phi_s^{NP} \approx -\phi_s$.

3.1. B_s Lifetime and Width Difference

A sample of ~ 2500 signal $B_s \rightarrow J/\psi\phi$ events collected with the CDF J/ψ trigger in 1.7 fb^{-1} of data was used to measure the B_s lifetime τ_s and decay width difference $\Delta\Gamma_s$ [19]. The B_s invariant mass distribution is seen in Figure 4 which shows good signal to background ratio. The B_s meson is a spin 0 particle which decays in two spin 1 particles J/ψ and ϕ . The total angular momentum in the final state can be 0, 1 or 2. The states with angular momentum 0 and 2 are CP even, while the state with angular momentum 1 is CP odd. One can statistically separate the CP even and CP odd states using their different angular distributions. In the case of CP conservation the mass eigenstates are also CP eigenstates. It is interesting to note that since in SM the CP violation phase in the B_s system is very small, the mass eigenstates are CP eigenstates with good approximation.

The B_s lifetime and decay width difference are extracted using an un-binned likelihood method in the space of mass, decay time and angles of the final state particles. There are three angles $\vec{\rho} = \{\cos\theta_T, \phi_T, \cos\psi_T\}$ that completely define the directions of the four particles μ^+, μ^-, K^+, K^- in the final state. These angles are defined in the transversity basis introduced in Ref. [20]. Figure 5 shows the B_s decay time distribution together with the fit projection. The largest systematic uncertainties on lifetime are due to decay time resolution model and alignment of the silicon detector. The largest systematic on $\Delta\Gamma$ is due to about 3% of $B^0 \rightarrow J/\psi K^{*0}$ decays reconstructed as $B_s \rightarrow J/\psi\phi$. The final results are: $c\tau = 1.52 \pm 0.04(\text{stat.}) \pm 0.02(\text{syst.})\text{ ps}$ and $\Delta\Gamma = 0.076^{+0.059}_{-0.063}(\text{stat.}) \pm 0.006(\text{syst.})\text{ ps}^{-1}$. The fractions of each of the three final state amplitudes are also measured and together with the lifetime and width difference are found to be in agreement with the similar measurement performed by the D0 experiment [21].

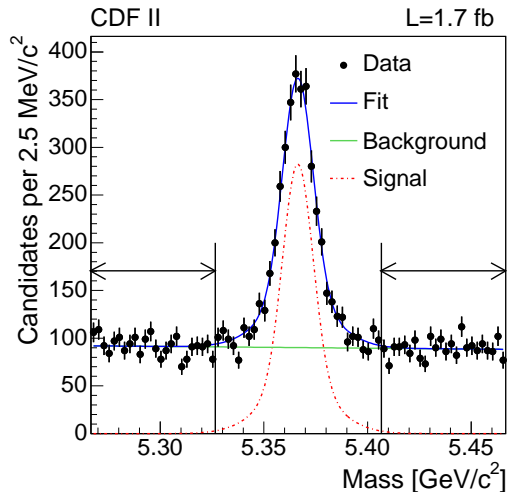


Figure 4. B_s invariant mass from $B_s \rightarrow J/\psi \phi$ decays. Fit projections are superimposed.

3.2. CP Violation in B_s System

The CP violation phase β_s in $B_s \rightarrow J/\psi \phi$ decays was measured for the first time by the CDF experiment using 1.4 fb^{-1} of data [22]. The analysis uses a sample of ~ 2000 signal events. To enhance our sensitivity to the CP violation phase, we identify the flavor of the B_s or \bar{B}_s meson at production by means of flavor tagging. Two independent types of flavor tags are used, each exploiting specific features of the production of b quarks at the Tevatron. The first type of flavor tag infers the production flavor of the B_s or \bar{B}_s meson from the decay products of the b hadron produced by the other b quark in the event. This is known as an opposite-side flavor tag (OST). The second type of flavor tag identifies the flavor of the reconstructed B_s or \bar{B}_s meson at production by correlating it with the charge of an associated kaon arising from fragmentation processes, referred to as a same-side kaon tag (SSKT). The average dilution D , defined via the correct tag probability $P = (1 + D)/2$, is $(11 \pm 2)\%$ for the OST and $(27 \pm 4)\%$ for the SSKT. The mea-

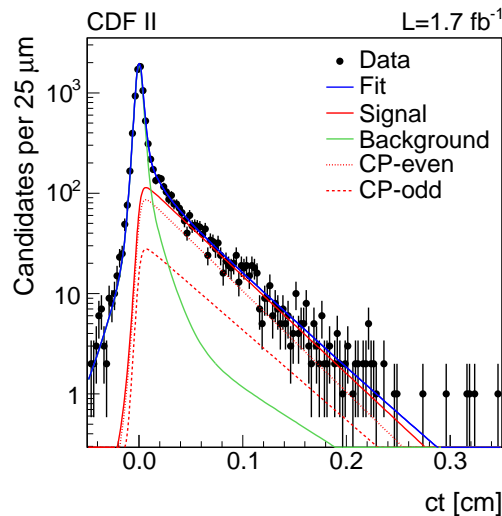


Figure 5. B_s decay time from $B_s \rightarrow J/\psi \phi$ decays. Fit projections are superimposed.

sured efficiencies for a candidate to be tagged are $(96 \pm 1)\%$ for the OST and $(50 \pm 1)\%$ for the SSKT.

An unbinned maximum likelihood fit is performed to extract the parameters of interest, $2\beta_s$ and $\Delta\Gamma$, plus additional parameters referred to as “nuisance parameters” which include the signal fraction f_s , the mean B_s width $\Gamma \equiv (\Gamma_L + \Gamma_H)/2$, the mixing frequency Δm_s , the magnitudes of the polarization amplitudes $|A_0|^2$, $|A_{\parallel}|^2$, and $|A_{\perp}|^2$, and the strong phases $\delta_{\parallel} \equiv \arg(A_{\parallel}^* A_0)$ and $\delta_{\perp} \equiv \arg(A_{\perp}^* A_0)$. The fit uses information on the reconstructed B_s candidate mass m and its uncertainty σ_m , the B_s candidate proper decay time t and its uncertainty σ_t , the transversity angles $\vec{\rho}$ and tag information \mathcal{D} and ξ , where \mathcal{D} is the event-specific dilution and $\xi = \{-1, 0, +1\}$ is the tag decision, in which $+1$ corresponds to a candidate tagged as B_s , -1 to a \bar{B}_s , and 0 to an untagged candidate.

The time and angular dependence of the signal PDF $P_s(t, \vec{\rho}, \xi, |\mathcal{D}, \sigma_t)$ can be written in terms of

two PDFs, P for B_s and \bar{P} for \bar{B}_s , as

$$P_s(t, \vec{\rho}, \xi | \mathcal{D}, \sigma_t) = \frac{1 + \xi \mathcal{D}}{2} P(t, \vec{\rho} | \sigma_t) \epsilon(\vec{\rho}) + \frac{1 - \xi \mathcal{D}}{2} \bar{P}(t, \vec{\rho} | \sigma_t) \epsilon(\vec{\rho}), \quad (2)$$

The detector acceptance effects on the transversity angle distributions $\epsilon(\vec{\rho})$ are modeled with $B_s \rightarrow J/\psi \phi$ simulated data. The time and angular probabilities for B_s can be expressed as

$$\begin{aligned} P(t, \vec{\rho}) \propto & |A_0|^2 \mathcal{T}_+ f_1(\vec{\rho}) + |A_{\parallel}|^2 \mathcal{T}_+ f_2(\vec{\rho}) \\ & + |A_{\perp}|^2 \mathcal{T}_- f_3(\vec{\rho}) + |A_{\parallel}| |A_{\perp}| \mathcal{U}_+ f_4(\vec{\rho}) \\ & + |A_0| |A_{\parallel}| \cos(\delta_{\parallel}) \mathcal{T}_+ f_5(\vec{\rho}) \\ & + |A_0| |A_{\perp}| \mathcal{V}_+ f_6(\vec{\rho}), \end{aligned} \quad (3)$$

where the functions $f_1(\vec{\rho}) \dots f_6(\vec{\rho})$ are defined in Ref. [19]. The probability \bar{P} for \bar{B}_s is obtained by substituting $\mathcal{U}_+ \rightarrow \mathcal{U}_-$ and $\mathcal{V}_+ \rightarrow \mathcal{V}_-$. The time-dependent term \mathcal{T}_{\pm} is defined as

$$\mathcal{T}_{\pm} = e^{-\Gamma t} \times [\cosh(\Delta\Gamma t/2) \mp \cos(2\beta_s) \sinh(\Delta\Gamma t/2) \mp \eta \sin(2\beta_s) \sin(\Delta m_s t)],$$

where $\eta = +1$ for P and -1 for \bar{P} . The other time-dependent terms are defined as

$$\begin{aligned} \mathcal{U}_{\pm} = \pm e^{-\Gamma t} \times & [\sin(\delta_{\perp} - \delta_{\parallel}) \cos(\Delta m_s t) \\ & - \cos(\delta_{\perp} - \delta_{\parallel}) \cos(2\beta_s) \sin(\Delta m_s t) \\ & \pm \cos(\delta_{\perp} - \delta_{\parallel}) \sin(2\beta_s) \sinh(\Delta\Gamma t/2)], \\ \mathcal{V}_{\pm} = \pm e^{-\Gamma t} \times & [\sin(\delta_{\perp}) \cos(\Delta m_s t) \\ & - \cos(\delta_{\perp}) \cos(2\beta_s) \sin(\Delta m_s t) \\ & \pm \cos(\delta_{\perp}) \sin(2\beta_s) \sinh(\Delta\Gamma t/2)]. \end{aligned}$$

The time-dependence is convolved with a Gaussian proper time resolution function with standard deviation σ_t , which is adjusted by an overall calibration factor determined from the fit using promptly decaying background candidates. The average of the resolution function is 0.09 ps, with a root-mean-square deviation of 0.04 ps.

Possible asymmetries between the tagging rate and dilution of B_s and \bar{B}_s mesons have been studied with control samples and found to be statistically insignificant. We allow important sources of systematic uncertainty, such as the determination of overall calibration factors associated with the proper decay time resolution and the

dilutions, to float in the fit. The mixing frequency $\Delta m_s = 17.77 \pm 0.12 \text{ ps}^{-1}$ is constrained in the fit within the experimental uncertainties [13]. Systematic uncertainties coming from alignment, detector sculpting, background angular distributions, decays from other B mesons, the modeling of signal and background are found to have a negligible effect on the determination of both $\Delta\Gamma$ and β_s relative to statistical uncertainties.

An exact symmetry is present in the signal probability distribution, as can be seen in Eq. (3), which is invariant under the simultaneous transformation ($2\beta_s \rightarrow \pi - 2\beta_s$, $\Delta\Gamma \rightarrow -\Delta\Gamma$, $\delta_{\parallel} \rightarrow 2\pi - \delta_{\parallel}$, and $\delta_{\perp} \rightarrow \pi - \delta_{\perp}$). This causes the likelihood function to have two minima. Since the log-likelihood function is non-parabolic and the two minima are barely separated at one standard deviation level, we cannot meaningfully quote point estimates. Instead we choose to construct a confidence region in the $2\beta_s - \Delta\Gamma$ plane.

We use the Feldman-Cousins likelihood ratio ordering to determine confidence levels (CL) in $2\beta_s - \Delta\Gamma$ space. The other parameters in the fit are treated as nuisance parameters (*e.g.* B_s mean width, transversity amplitudes, strong phases). To ensure that the obtained confidence regions provide the quoted coverage against deviations of the nuisance parameters from their values measured in our fit to data, we perform pseudo-experiments by randomly sampling the nuisance parameter space within $\pm 5\sigma$ of the fit values and confirm coverage of the 68% and 95% confidence regions shown in Fig. 6. The solution centered in $0 \leq 2\beta_s \leq \pi/2$ and $\Delta\Gamma > 0$ corresponds to $\cos(\delta_{\perp}) < 0$ and $\cos(\delta_{\perp} - \delta_{\parallel}) > 0$, while the opposite is true for the solution centered in $\pi/2 \leq \beta_s \leq \pi$ and $\Delta\Gamma < 0$. Assuming the standard model predicted values of $2\beta_s = 0.04$ and $\Delta\Gamma = 0.096 \text{ ps}^{-1}$ [17], the probability to observe a likelihood ratio equal to or higher than what is observed in data is 15%. Additionally, we present a Feldman-Cousins confidence interval of $2\beta_s$, where $\Delta\Gamma$ is treated as a nuisance parameter, and find that $2\beta_s \in [0.32, 2.82]$ at the 68% confidence level. The CP phase $2\beta_s$, $\Delta\Gamma$, Γ , and the linear polarization amplitudes are consistent with those measured in Ref. [19] and in Ref. [21].

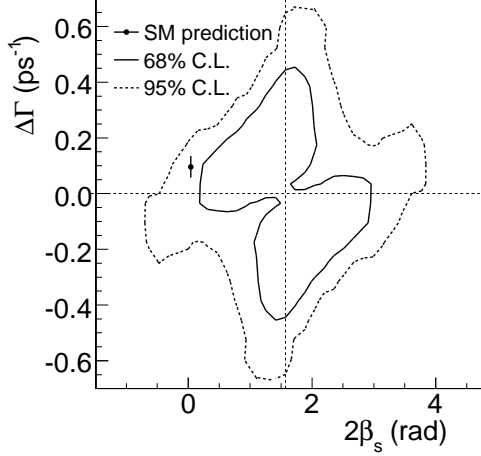


Figure 6. Confidence region in the $2\beta_s - \Delta\Gamma$ plane, where the standard model favored point is shown with error bars [17].

3.3. B_s Lifetime in Flavor Specific Decays

The lifetime of the B_s meson is measured by the CDF collaboration in flavor specific $B_s \rightarrow D_s \pi X$ decays [23] using 1.3 fb^{-1} of data. The flavor of the B_s meson at decay is given by the charges of the final state particles, hence the name “flavor specific”. These events are collected by a trigger which requires two tracks with impact parameter between $120 \mu\text{m}$ and 1 mm , specific to hadronic B decays. The sample contains ~ 1100 fully reconstructed $B_s \rightarrow D_s(\phi\pi)\pi$ and ~ 2200 partially reconstructed decays. Figure 7 shows the B_s invariant mass distribution and details of all contributions to partially reconstructed decays.

There are two main challenges in this analysis. First, the lifetime distribution of the B_s meson is biased due to the trigger that requires tracks with large impact parameter. This is corrected by using an efficiency function determined from simulation. This method is validated on control samples of $B^0 \rightarrow D^-\pi^+$, $B^0 \rightarrow D^{*-}\pi^+$ and $B^+ \rightarrow \bar{D}^-\pi^+$ decays where good agreement with the B^0 and B^+ world average lifetimes is

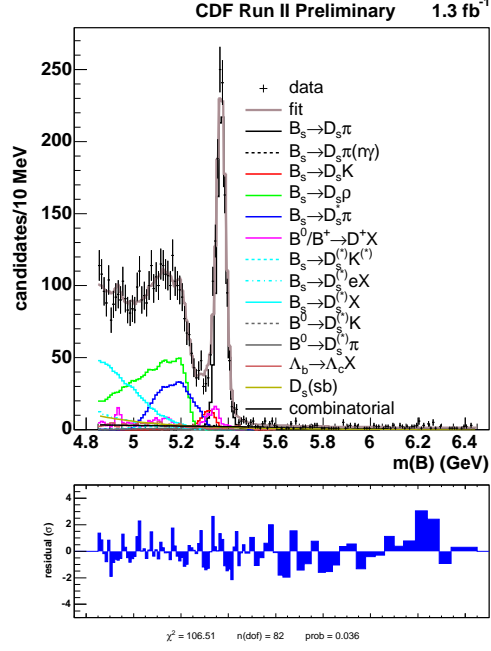


Figure 7. Invariant B_s mass distribution and fit projection.

obtained. A second challenge is to determine background models from the upper B_s mass side-band as well as from wrong sign $B_s \rightarrow D_s^+ \pi^+$ events. Additionally, we determine from simulation the mass distributions and momentum correction of partially reconstructed modes. The main systematic uncertainties come from background modeling. The measured lifetime is $c\tau_s = 455.0 \pm 12.2(\text{stat.}) \pm 7.4(\text{syst.}) \mu\text{m}$. This is the best measurement in flavor specific decays and agrees very well with both CDF and D0 measurements in $B_s \rightarrow J/\psi \phi$ decays discussed in section 3.1. We note that the lifetime measured in flavor specific decays is not exactly the inverse of the decay width as measured in $B_s \rightarrow J/\psi \phi$ decays. The actual relation between the measured quantity in flavor specific decays and the actual lifetime is: $\tau(B_s^0)_{FS} = \frac{1}{\Gamma} (1 + (\frac{\Delta\Gamma}{2\Gamma})^2) / (1 - (\frac{\Delta\Gamma}{2\Gamma})^2)$ which includes a small correction which depends

on the width difference $\Delta\Gamma$. It is also interesting to note that this measurement together with the lifetime measurements in $B_s \rightarrow J/\psi\phi$ decays from both CDF [19] and D0 [21] are larger than the 2007 world average [18] (1.41 ± 0.04 ps). The new world average B_s lifetime will be much closer to the B^0 lifetime as predicted theoretically.

4. Summary

We have presented recent CDF results on B_c and B_s meson properties. The best B_c mass measurement was performed by CDF in fully reconstructed $B_c \rightarrow J/\psi\pi$ decays. Measurements of the B_c lifetime in semileptonic decays agrees with the measurement from the D0 experiment and has similar precision. These measurements provide useful information that can be used to improve theoretical models used to study heavy mesons. The recent measurements of the B_s lifetime in both $B_s \rightarrow J/\psi\phi$ and flavor specific $B_s \rightarrow D_s\pi$ channels confirm the theoretical predictions that $\tau_s \approx \tau_d$. The measurements of the decay width difference $\Delta\Gamma$ and the CP violation phase β_s are statistically limited but open the road for exciting results with full Tevatron data sets.

I would like to thank the organizers of BEACH 2008 conference for an enjoyable experience and my CDF colleagues and Fermilab staff for their dedication which makes these results possible.

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